BBC RD 1977/34

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RESEARCH DEPARTMENT

REPORT

A 2·5 GHz circularly polarized aerial

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October 1977

BBC RD 1977/34
UDC 621.396.677.32
621.3.029.64

A 2·5 GHz CIRCULARLY POLARIZED AERIAL

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Summary

A circularly polarized aerial for operation in the 2·5 GHz frequency band is described in this report.

The aerial can be used in linear horizontal and vertical polarization modes as well as in left or right hand circular polarization modes. It has been specially developed for experimental outside broadcast propagation tests at these frequencies.

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October 1977

(RA-166)

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1. Introduction

S.H.F. radio links are frequently used in outside broadcast applications. Under ideal operating conditions the link can be established over unobstructed line-of-sight paths. However, circumstances can require temporary links to be operated over terrain which is far from ideal, the direct path being partially or even completely obstructed. In these situations, attempts are made to use indirect path signals and it is not unknown, in the extreme case, for the link to be established by bouncing the transmitted signal from tall buildings or other large objects.

It has been suggested that for these conditions one particular form of wave polarization may exhibit better propagation characteristics than others, i.e. give greater signal at the receiving site or show less impairment by delayed signals.

The effect of the polarization mode on the received signals is currently being investigated and it has been necessary to develop a small portable aerial for these tests. The requirements for the aerial are that it should be capable of radiating linear or circularly polarized waves at frequencies of 2·46, 2·56 and 2·66 GHz. It should also be lightweight and offer low wind resistance so that it can be mounted and operated satisfactorily on a light mast.

The choice of aerial for this application is limited. Three aerial types were considered: the parabolic dish, the horn radiator and the end-fire array. Of these, the dish and horn radiators tend to have larger dimensions than the end-fire array for a given power gain. The dish aerial is not easy to fabricate. Difficulties can occur with cross-coupling between modes in the waveguide feeding the horn radiator, which affects the independence of the vertical and horizontal field components. Of all three types of aerial, the end-fire array, constructed in the form known as a 'cigar aerial',[1] is considered to offer the best compromise in its performance.

2. Cigar aerial

The cigar[1] aerial is of the yagi type having parasitic elements in the form of conducting discs. It is often considered as an artificial dielectric rod aerial. The bandwidth of the aerial is generally thought to be better than that of a yagi array but, in the case of a long array, the discs have been replaced by rods having lengths equal to the disc diameters with apparently only slight changes to its radiation characteristics.[2] However, the use of disc parasitic elements does have a particular advantage in that a change of polarization can be made simply by rotating the driven element about the aerial axis.

The basis for the aerial design described in this report is from published dimensions[3] for the director discs of a 3·0 GHz aerial. Modifications to the scaled dimensions have been made to improve the performance with the aerial when protected by a weather shroud.

3. Aerial construction

The aerial comprises two parts: the radiating section and the feeder housing and mounting assembly.

The radiating section, shown in Fig. 1, consists of a pair of driven elements, parasitic directors and a reflector. The driven elements are folded dipoles. Each dipole is constructed from brass rod, the diameter of the driven limb being slightly greater than that of the grounded limb. This gives impedance transformation of approximately 3:4:1 referred to a fully driven dipole. Each dipole is fed from a $\lambda/2$ balun constructed from miniature semi-rigid feeder type CA50047.

A metal tube boom is used to support the metal disc directors and the folded elements. The reflector, which also forms the endplate for the feeder housing and mounting assembly, supports the director boom by way of a symmetrical arrangement of four metal rods passing between adjacent dipole limbs.

A schematic diagram giving the dimensions of the elements is shown in Fig. 2 and of the driven element arrangement in Fig. 3.

The whole of the radiating section is housed in a glass-fibre shroud, see Fig. 4.

The feeder housing and mounting assembly consists of a metal cylinder fitted with end plates (one being the reflector for the radiating section) and a short scaffold tube. The interior of the cylinder contains a feeder terminal sub-assembly which supports all internal connectors and a directional coupler with an equal-power output ratio. The coupler, used to provide the quadrature drive for the dipoles when the aerial is operated in the circular polarization mode, is made up from a commercially available 50Ω flexible coupler mounted on a printed circuit board.

The dipole feeders are brought from the radiating section through the reflector end plate and terminated in miniature connectors (type SMC) on the sub-assembly plate. Matching stubs are also incorporated in the feeder in this section and can be seen in Fig. 1.

The input to the whole aerial is via a type-N socket mounted on the cylinder wall; connection to a SMC socket mounted on the sub-assembly plate is by way of a miniature flexible cable type RG188A/V.

The arrangement of connectors on the termination sub-assembly is such that any of the polarization modes can be achieved by interchanging the connection of three semi-rigid cable links.

The link positions for the various polarization modes are shown in Table 1.

TABLE 1

	Socket connections by U-link
Vertical polarization	1 to 0
Horizontal polarization	6 to 0
Clockwise circular polarization*	2 to 0, 1 to 3, 6 to 4** Socket 5 terminated in 50Ω load
Counter-clockwise circular* polarization	2 to 0, 1 to 4, 6 to 3** Socket 5 terminated in 50Ω load

* The terms clockwise or counter-clockwise circular polarization used here, give the direction of rotation of the field vector as a function of time when viewed from behind the aerial whilst transmitting.

** when the aerial is powered in the circular polarization mode it is essential that the coupler ports are terminated with the correct u-link connections.

4. Radiation pattern

The E- and H-plane radiation patterns of the aerial driven in the linear polarization mode are shown in Figs. 5 and 6. As the aerial construction is symmetrical about the support boom axis, the radiation patterns apply when either dipole is driven alone. If the aerial is set to radiate vertical polarization, the H-plane radiation applies in the horizontal plane and the E-plane radiation pattern in the elevation plane. For horizontal polarization the converse is true.

The circularity of the wave front with the aerial set to radiate in the circular polarization mode, depends on the equality of the amplitudes and phases of the dipole feed currents, which in turn depend on the performance of the directional coupler. The circularity also depends on the equality of E- and H-plane radiation patterns and on their relative phases. Small phase errors can occur (apart from the coupler error) from lack of identity in the balun and aerial elements.

Measurements of circularity were made by continuously swinging a linearly polarized 'look aerial' about its axis from horizontal through vertical to horizontal polarization while rotating the circularly polarized test aerial in the horizontal plane. These tests show that the axial ratio* does not exceed 1·05 (0·5 dB) on the main lobe axis. They also show that the axial ratio of the radiated field becomes larger as the angle from the main lobe axis increases, mainly as a result of differences between the E and H-plane patterns. Fig. 7 is a plot of the main lobe of the circularly polarized radiation pattern at 2·56 GHz, measured in this way. The maximum and minimum values of the ripple superimposed on the general radiation pattern shape correspond approximately to the semi-major and semi-minor axis values of the wave-front ellipse; the axial ratio with bearing is given in decibels by the difference in amplitude of adjacent maxima and minima.

5. Impedance

The input impedance of the aerial was measured using a network analyser. The resulting reflection coefficient ρ (referred to 50Ω) at one of the SMC sockets, mounted on sub-assembly plate, feeding one dipole element is shown in Fig. 8. At these frequencies the effects of discontinuities in cables and connectors become very apparent and where multi-connector leads are used, the input impedance of the aerial is modified. This is also shown in Fig. 8; both curves should be the same, the difference is due to the addition of SMC sockets and plugs, a semi-rigid cable link, a miniature flexible cable and type-N socket.

Fig. 9 shows the reflection coefficient at the type-N socket input, with the array connected in a circular polarization mode.

6. Gain

The intrinsic gain of the aerial has been calculated from the radiation patterns and is 13·4, 13·5 and 13·6 dB, relative to a λ/2 dipole at 2·46, 2·56 and 2·66 GHz respectively.

7. Power handling capacity

The maximum power input to the aerial in the circular polarization mode depends on its reflection coefficient and the rated power of the coupler terminating load. Assuming the reflection coefficient of the aerial can reach 20% and a maximum dissipation of 1W in the terminating load, the maximum permissible power input to the aerial is 25 Watts.

8. Conclusions

The cigar aerial offers a satisfactory design meeting the operational requirements for the propagation tests.* Higher gains could be achieved by development of a longer aerial, but in doing so its compact configuration would be spoilt. Alternatively, the gain could be increased by stacking a number of the aerials together without resorting to further work on the arial itself.

9. References

1. SIMON, J.C. *and* BIGGI, V. Un nouveau type d'aerien et son application a la transmission de television a grande distance. *L'onde Electrique*, Vol. XXXIV, No. 332, Nov. 1954.

2. MALECH, R.G. Light weight high-gain antenna. IRE National Convention Record. Antennas and Propagation Microwave Theory and Techniques, Part 1, 1958, March 24 – 27.

3. THOUREL, L. The Antenna. Chapman and Hall, London, 1960, pp. 178 – 183.

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* axial ratio is defined as the ratio of semi-major axis to semi-minor axis of the wave-front ellipse. For circular polarization the ratio is 1; for linear polarization the ratio is infinity.

* Much of the design and measurement work was carried out by Mr. D.J. Darlington.

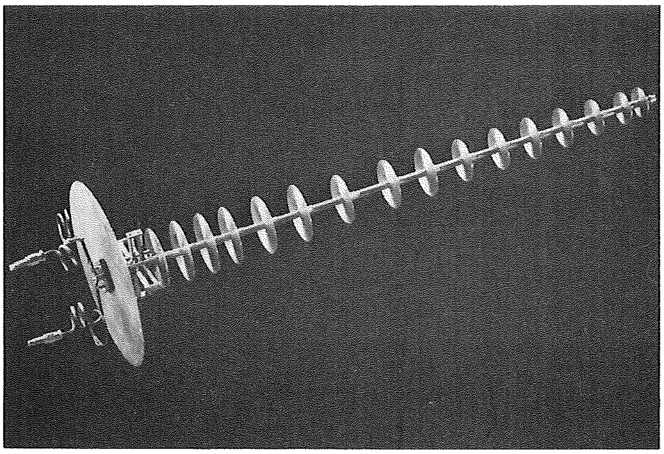
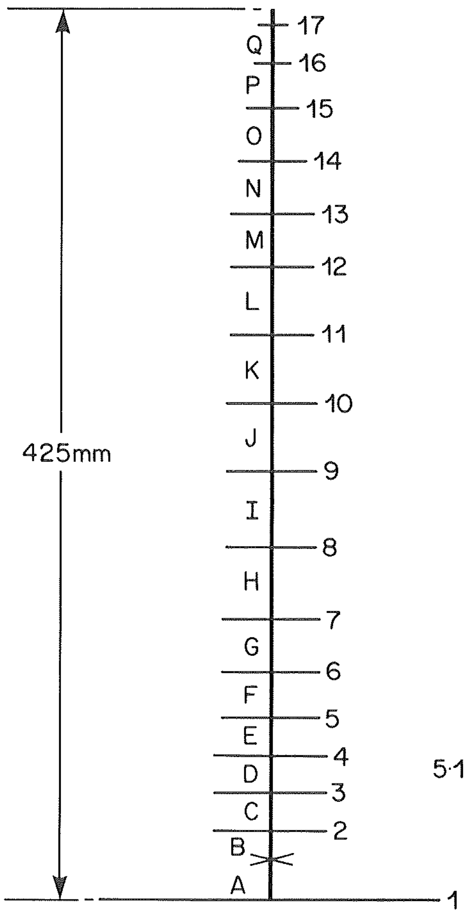


Fig. 1 - Radiating section of the aerial array



Disc Diameter	Spacing
1. 126mm	A. 21mm
2. 45·1	B. 12
3. 45·1	C. 16·2
4. 45·1	D. 16·2
5. 43·4	E. 16·2
6. 43·4	F. 23
7. 43·4	G. 25·5
8. 37·6	H. 30·5
9. 37·6	I. 34·8
10. 37·6	J. 27·8
11. 33·0	K. 27·8
12. 33·0	L. 27·8
13. 33·0	M. 25·5
14. 31·3	N. 25·5
15. 28·9	O. 25·5
16. 26·6	P. 23·0
17. 24·9	Q. 13·9

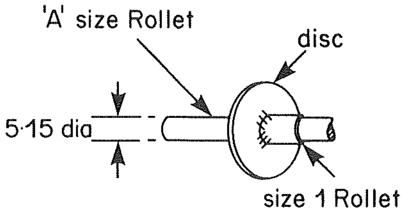


Fig. 2 - Dimensions and spacings of disc elements

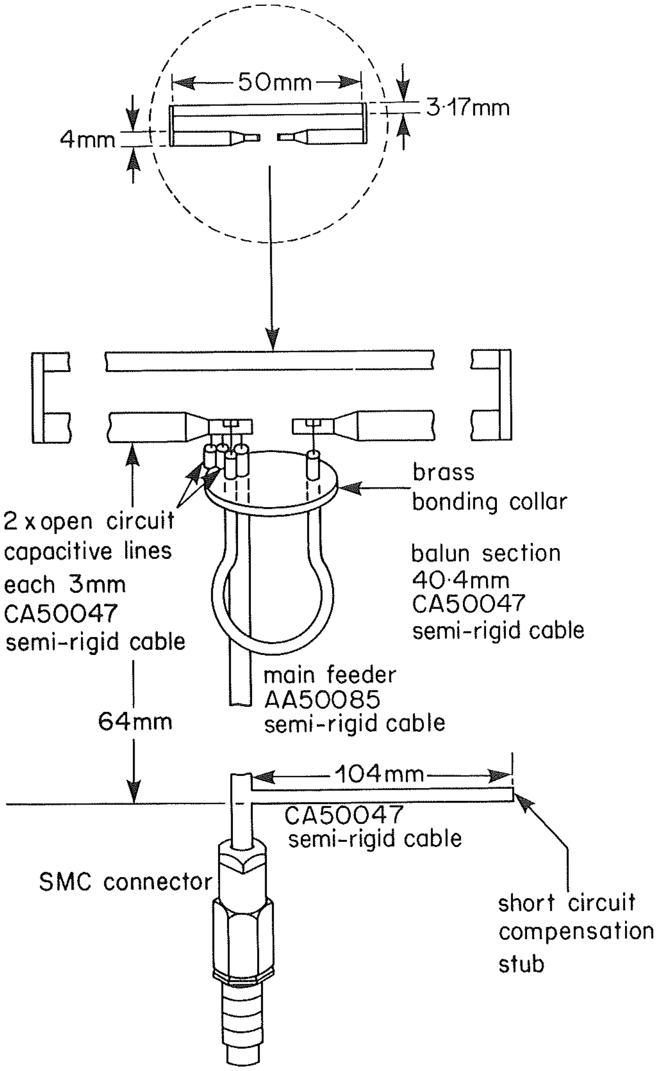
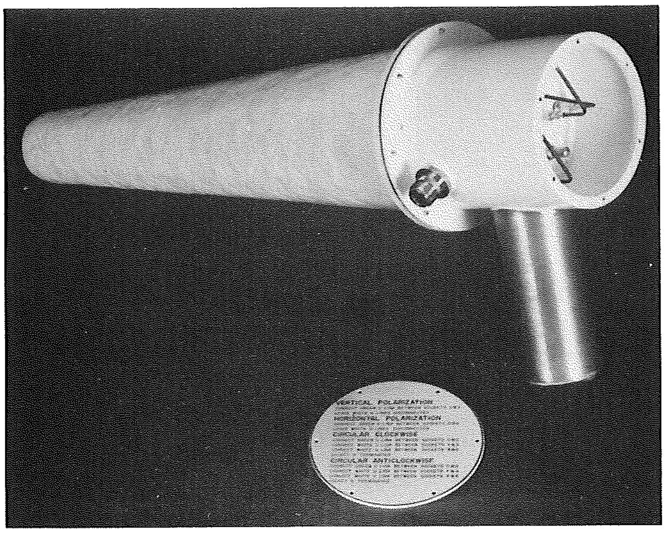


Fig. 3 - Driven element and balun arrangement

Fig. 4 - Complete aerial



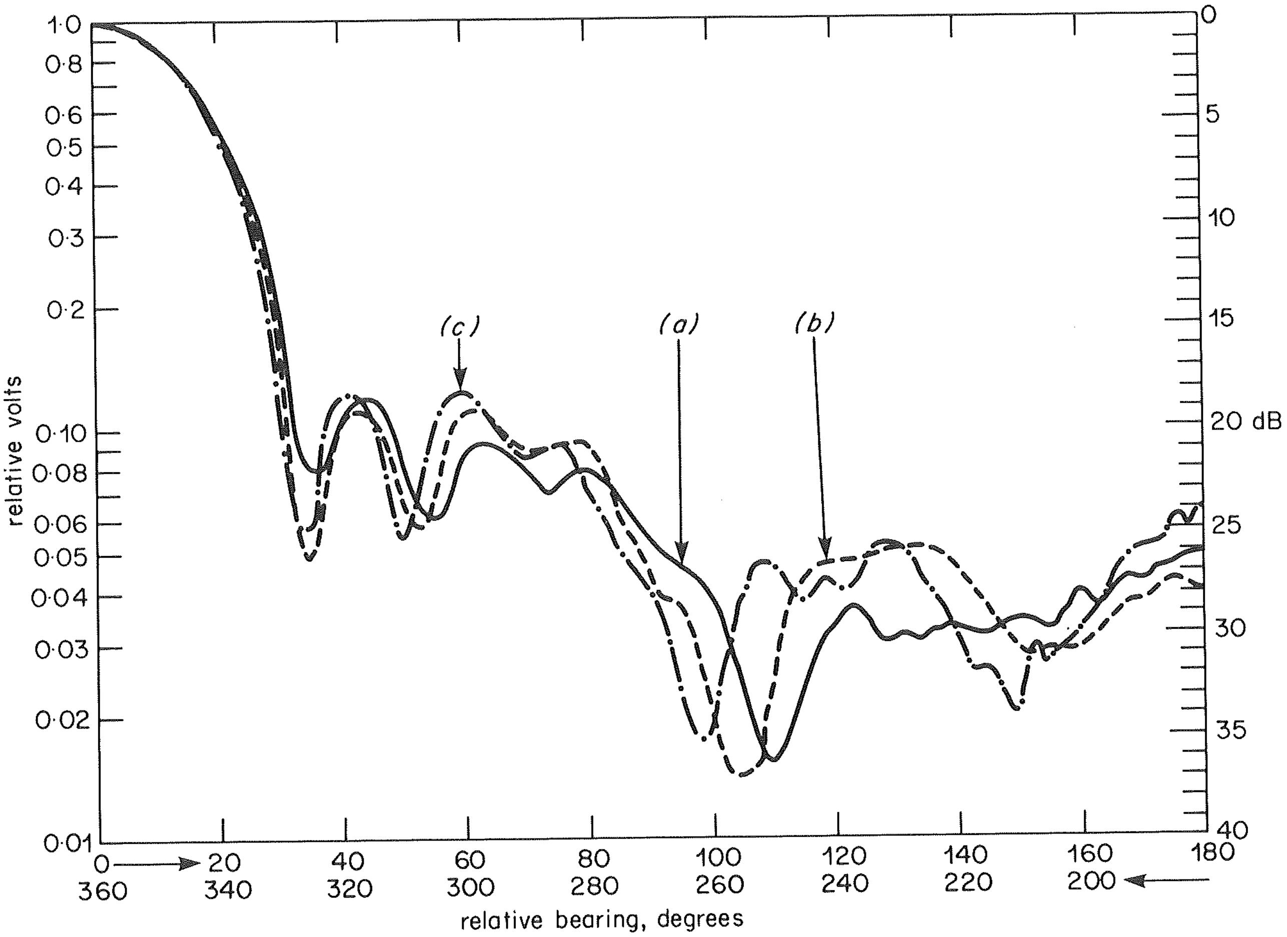


Fig. 5 - H-plane radiation pattern

(*a*) 2·46 GHz (*b*) 2·56 GHz (*c*) 2·66 GHz

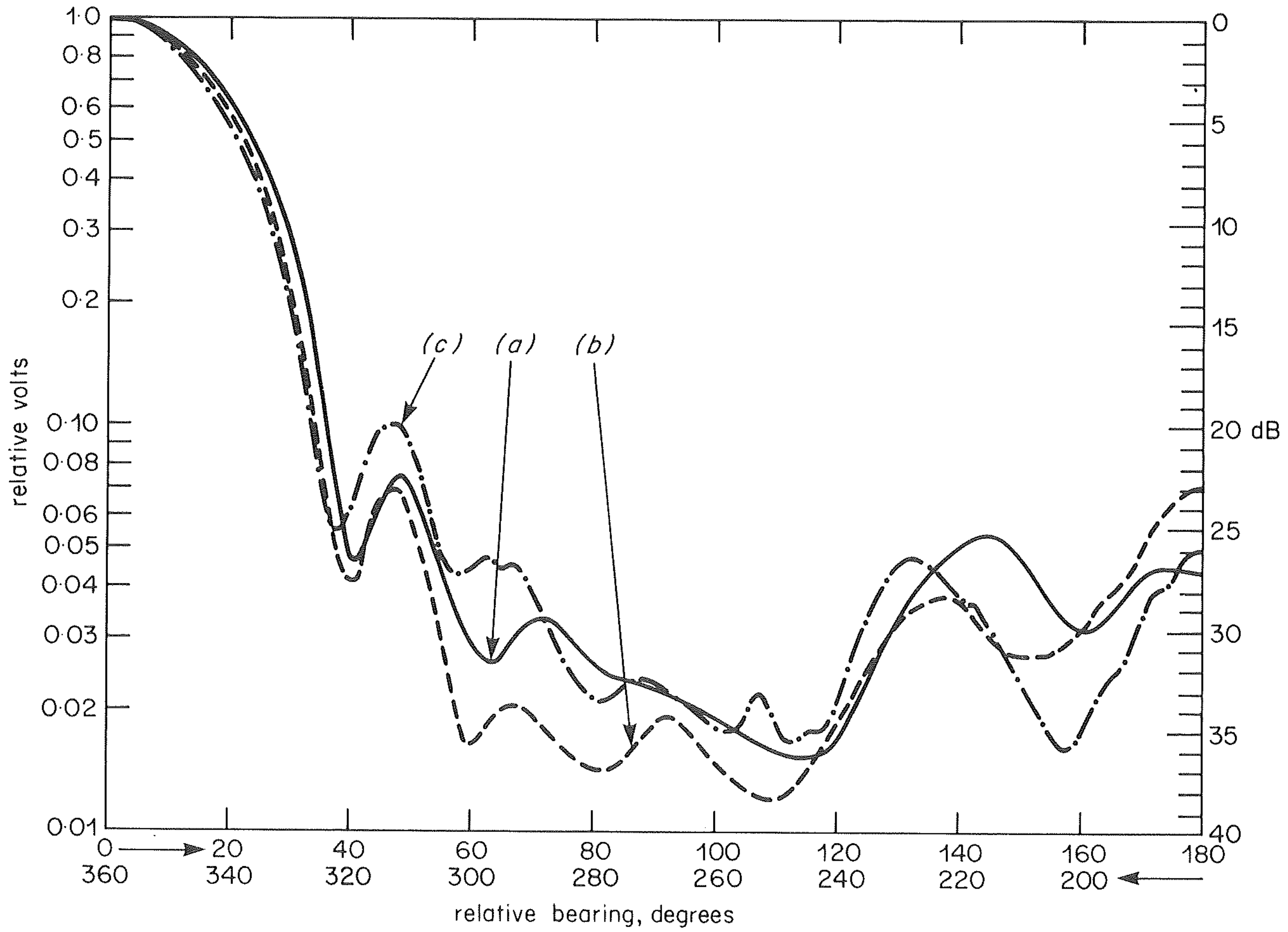


Fig. 6 - E-plane radiation patterns
(*a*) 2·46 GHz (*b*) 2·56 GHz (*c*) 2·66 GHz

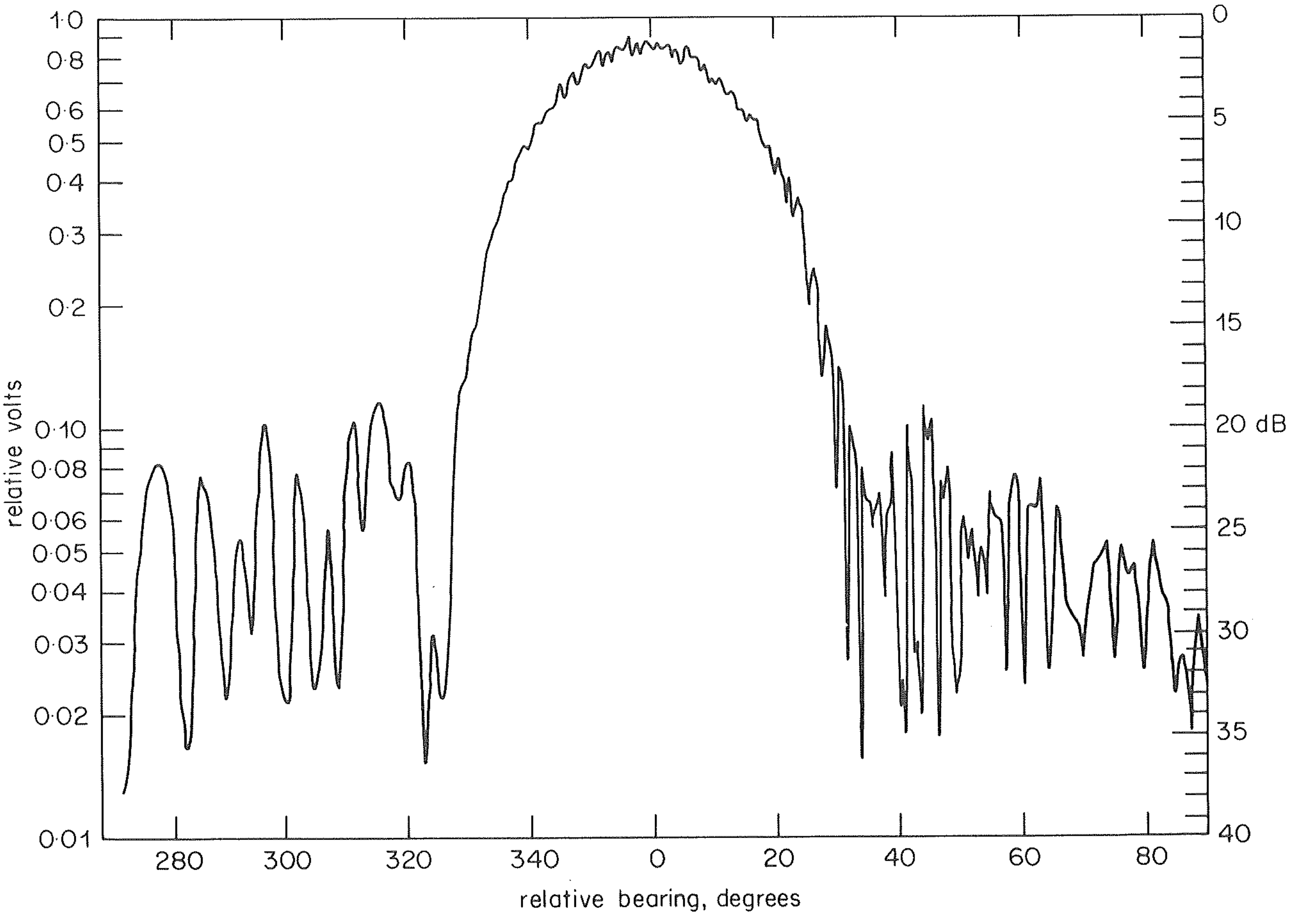


Fig. 7 - Circular polarization radiation pattern showing the effective aerial ratio

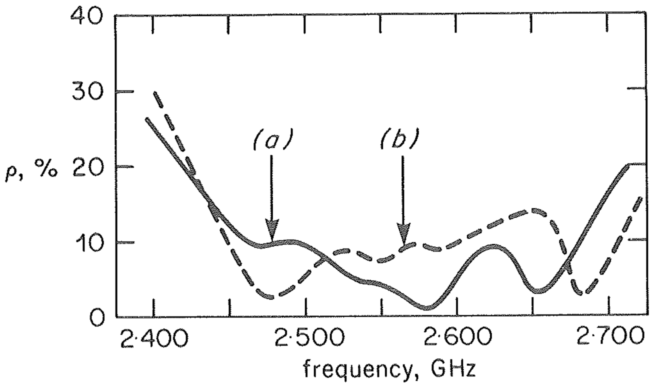


Fig. 8 - Reflection coefficient of the aerial in the linear polarization mode

(*a*) SMC socket input (*b*) type-N socket input

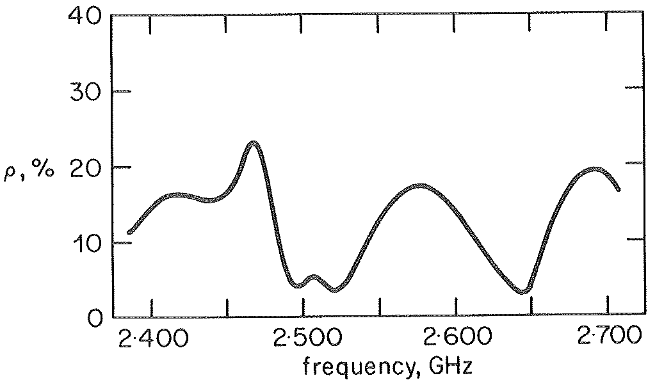


Fig. 9 - Reflection coefficient of the aerial in the circular polarization mode

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